





WARD & SMITH - A NEW ASTRONOMICAL INSTRUMENT - LONDON 1735







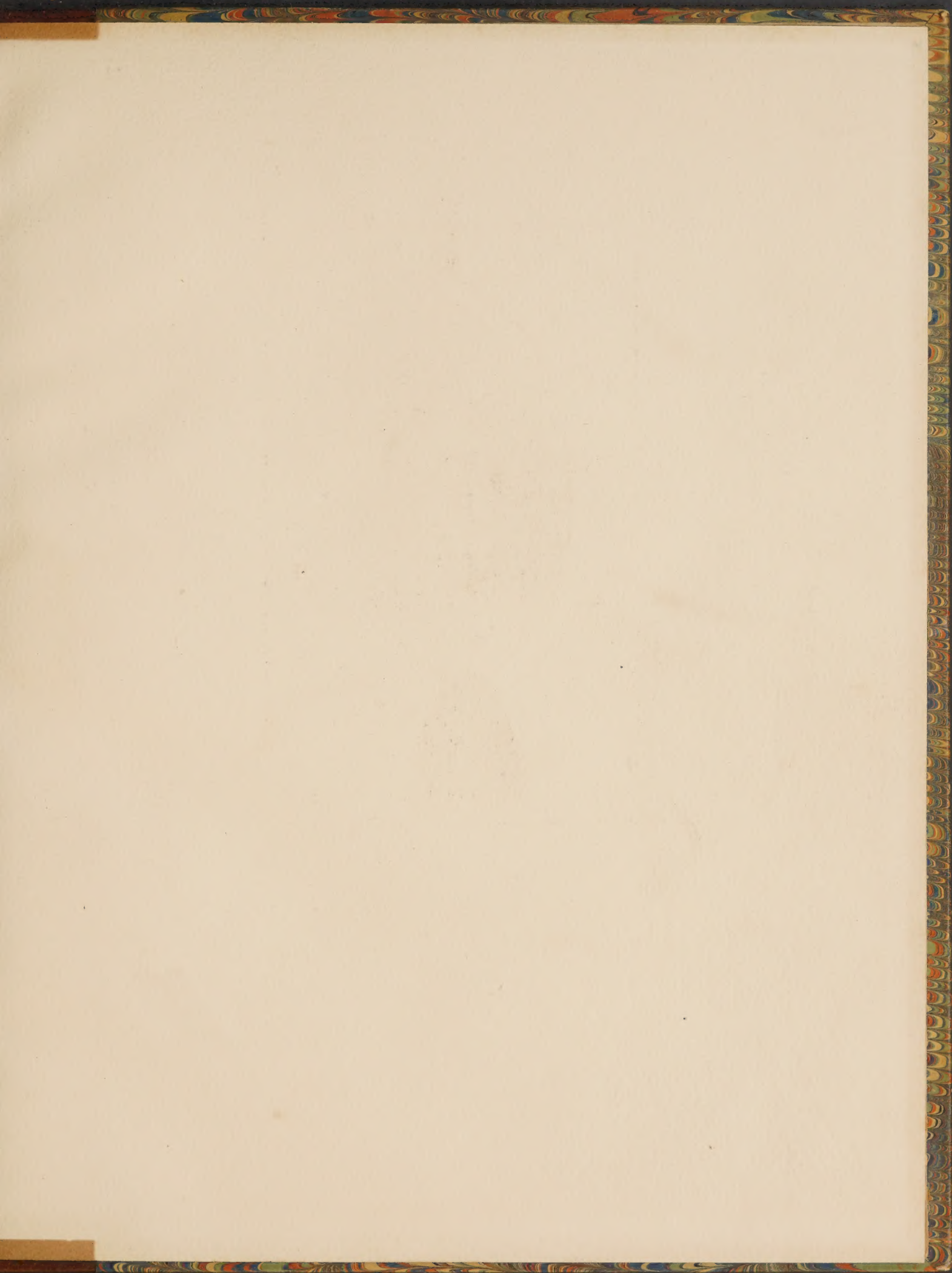


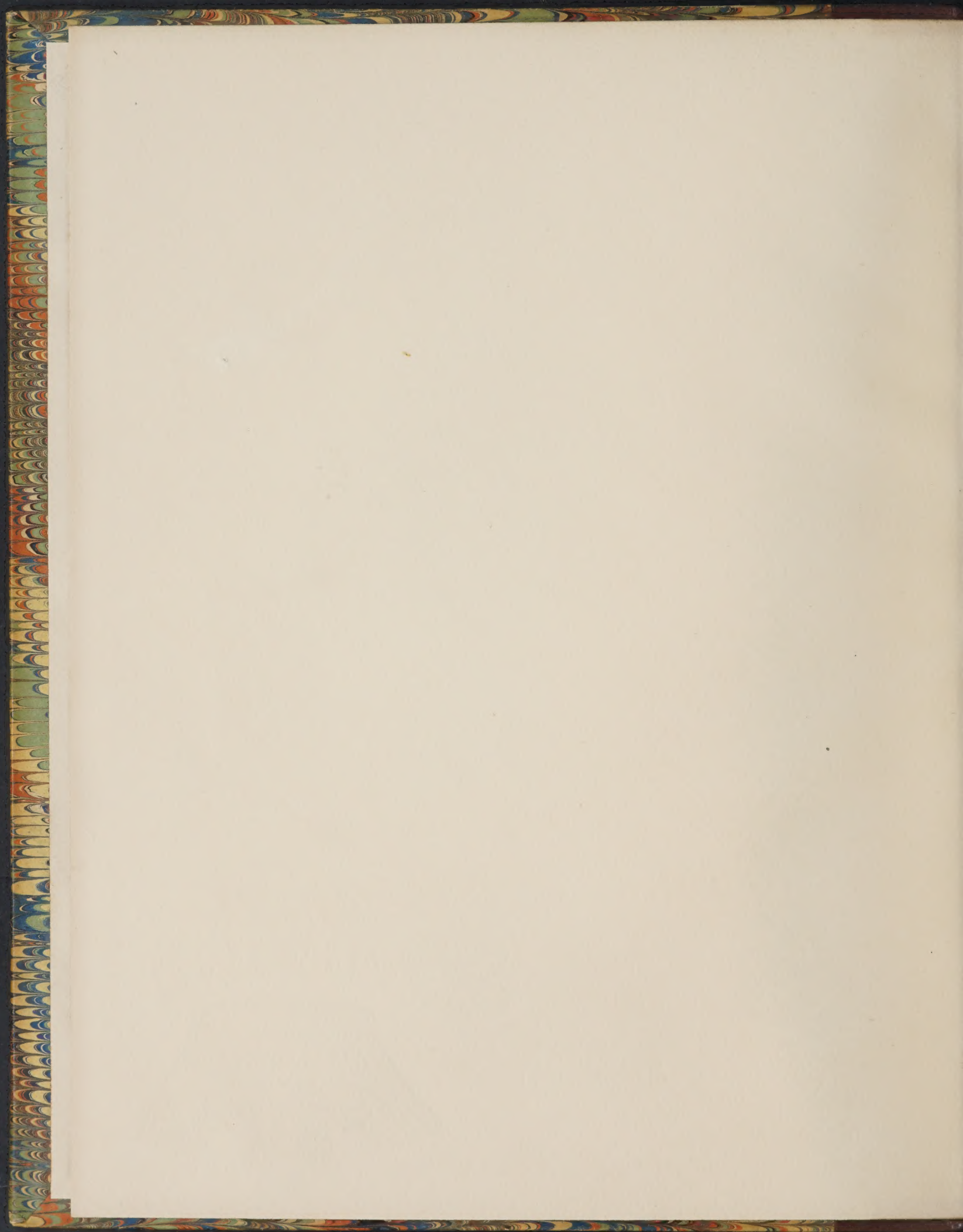
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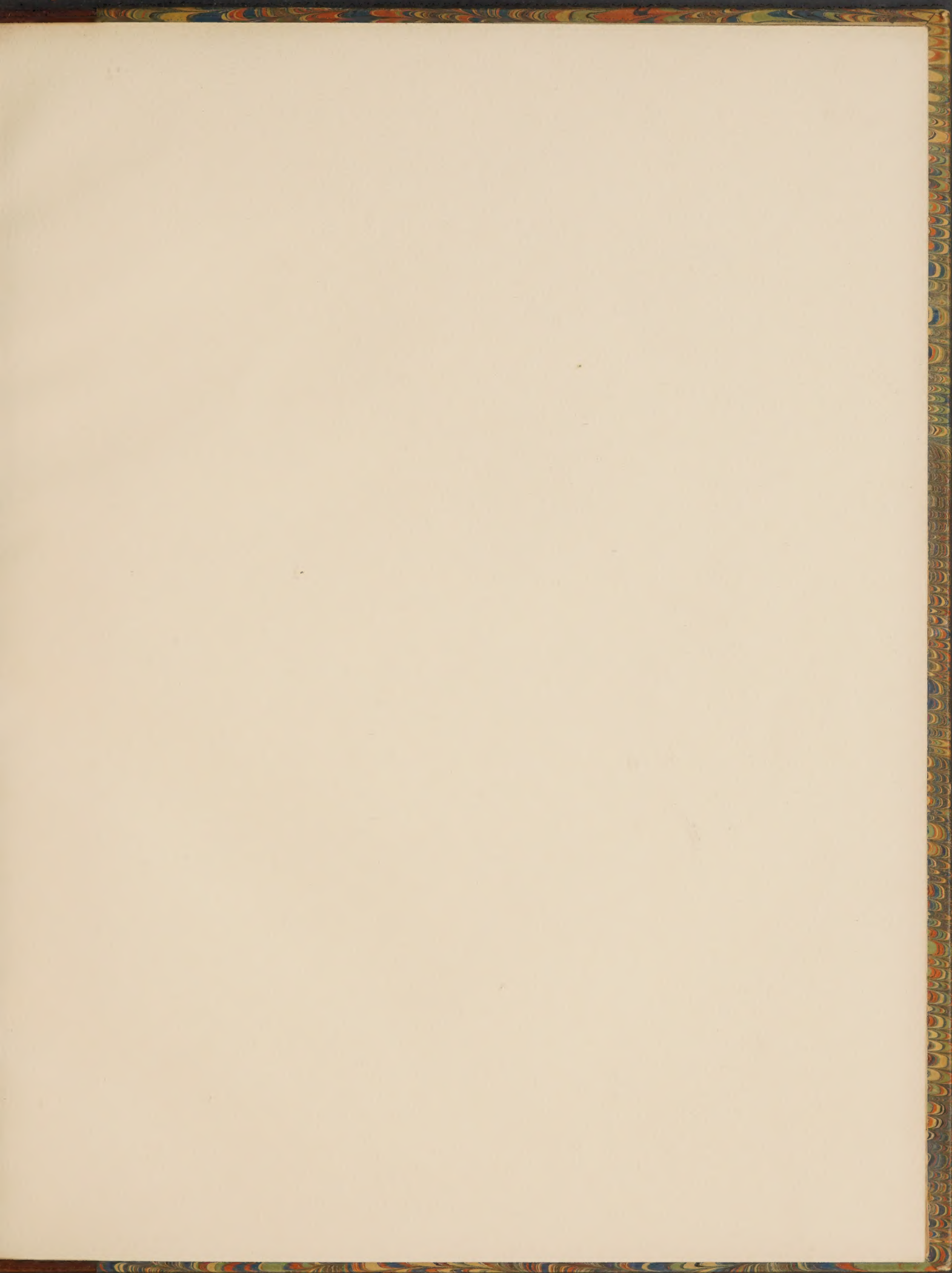
*Thomas Bell*



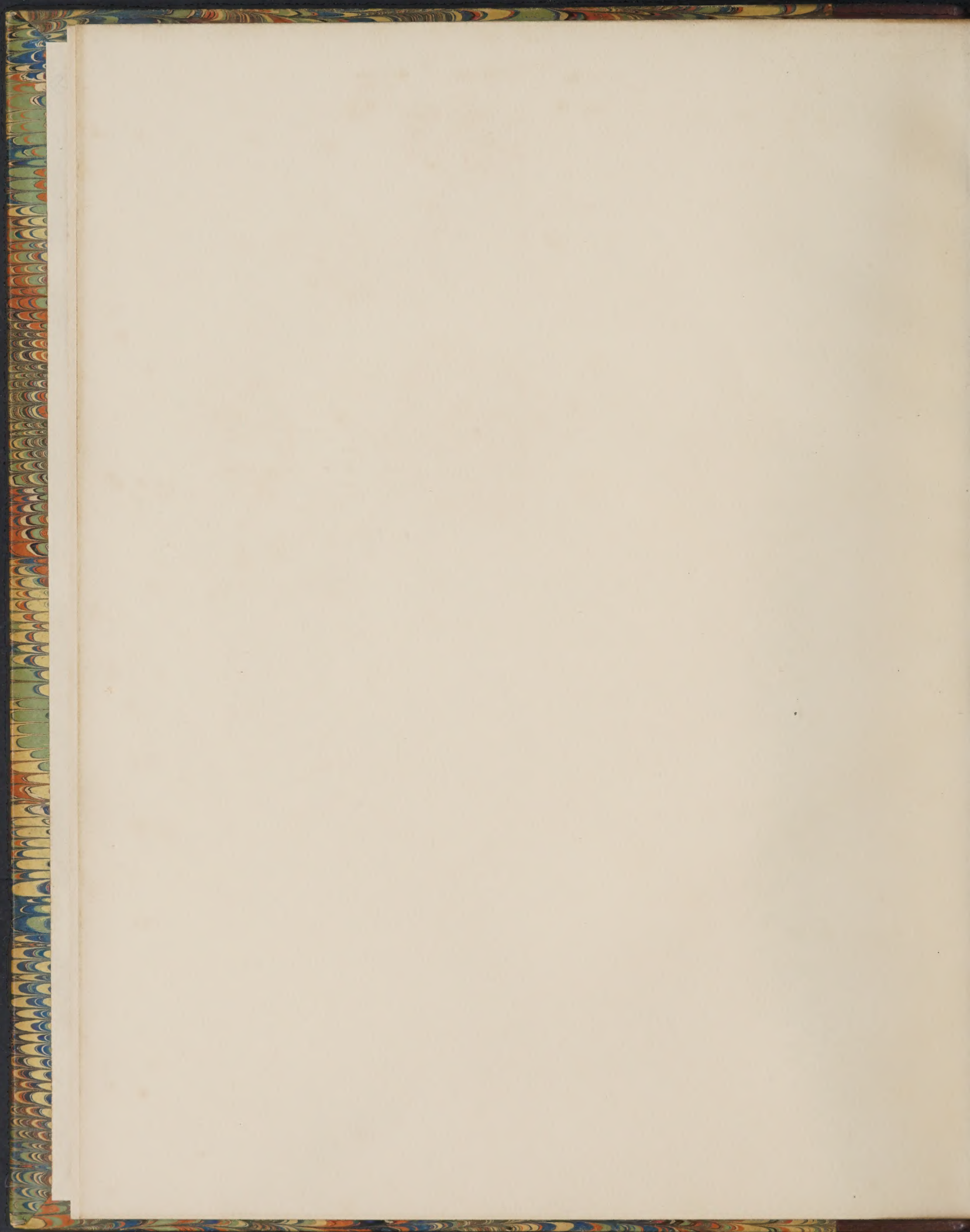




















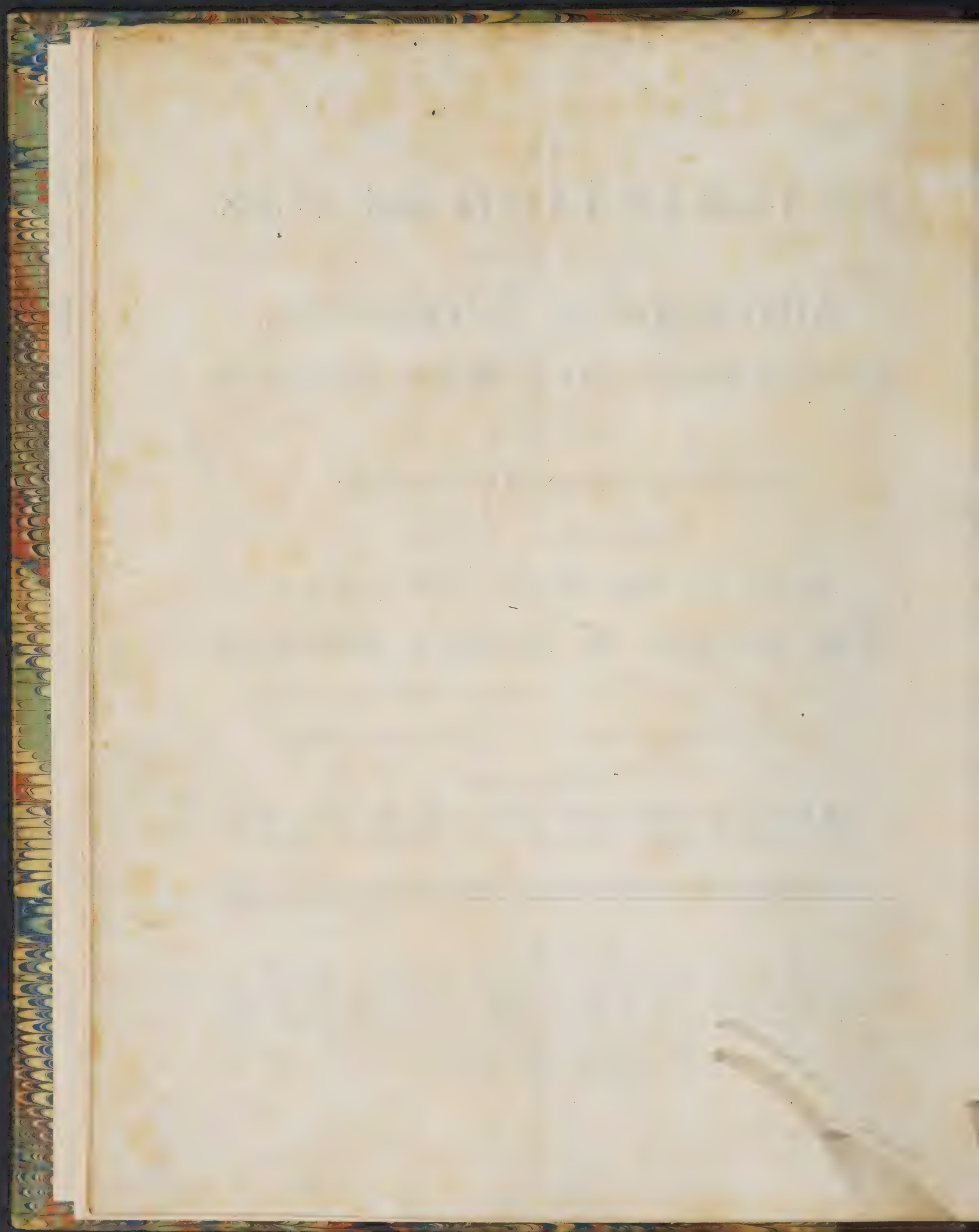


THE  
DESCRIPTION and USE  
OF A NEW  
Astronomical Instrument,  
For taking ALTITUDES of the SUN and STARS  
at SEA,  
WITHOUT an HORIZON;  
TOGETHER WITH  
An Easy and Sure METHOD of OBSERVING  
The *Eclipses of Jupiter's Satellites*,  
Or any other PHOENOMENON of the like Kind, on *Ship-board*;  
In order to determine the DIFFERENCE of MERIDIANS at SEA.  
To which are added,  
TABLES for computing the *Times* when the *Eclipses* of the  
*First Satellite of Jupiter* happen under the *Meridian* of *London*.

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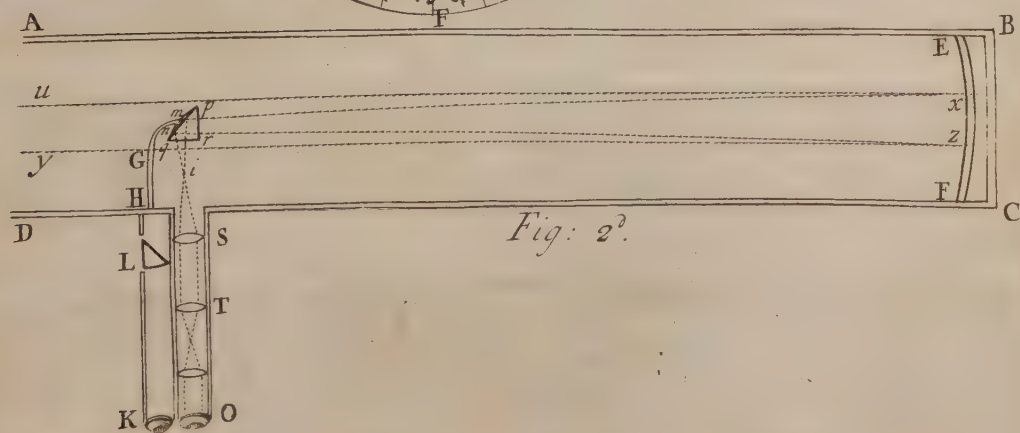
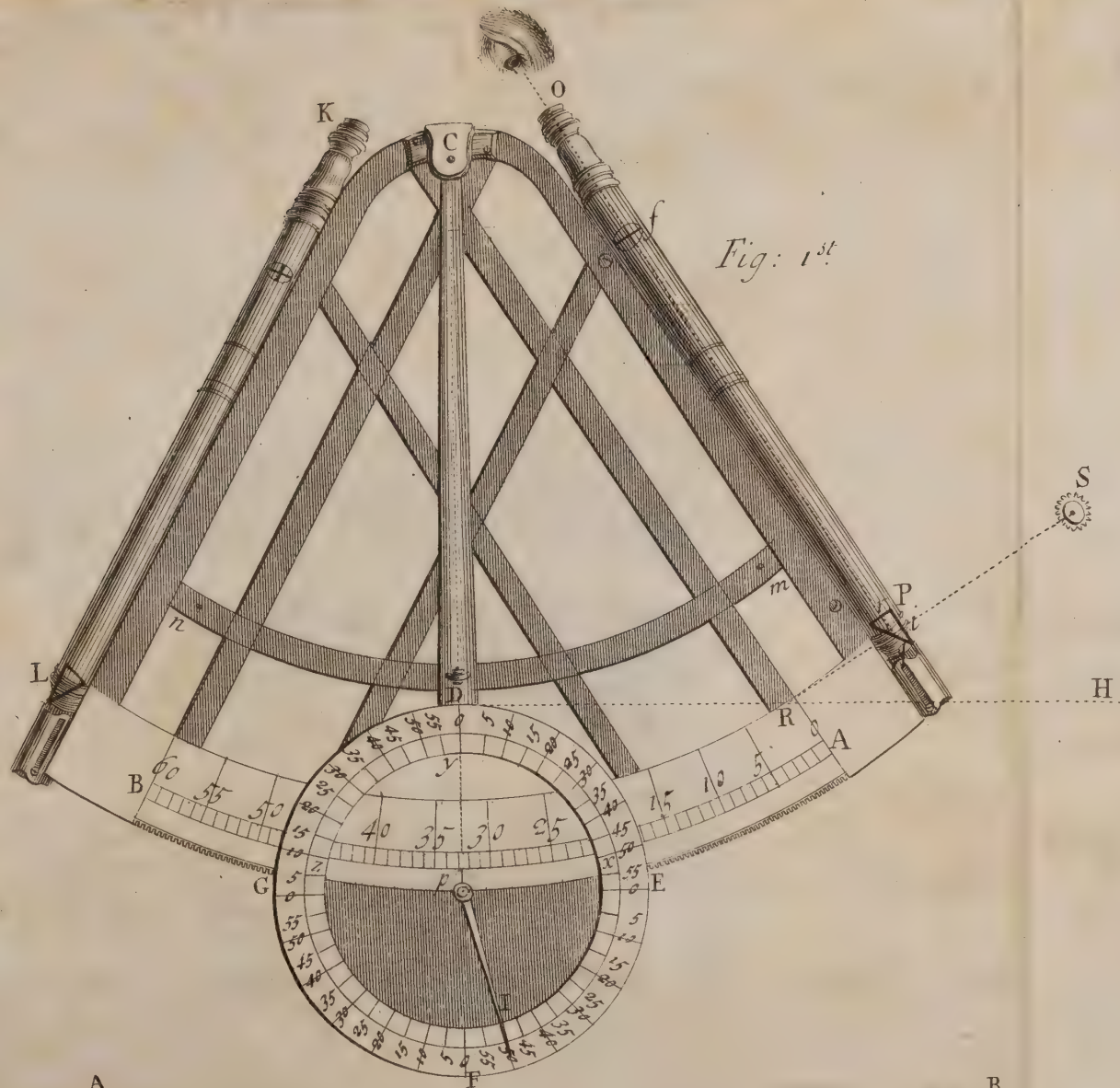
L O N D O N :

Printed for G. STRAHAN, W. MEADOWS, and J. CLARKE, in *Cornhill*; C. RIVINGTON, W. INNYS and R. MANBY, in *St Paul's Church-Yard*; J. MANN, *Optician*, at the *Archimedes*, and J. SENEX, against *St Dunstan's Church* in *Fleet-street*; C. WARD and R. CHANDLER, between the *Temple-Gates*, and at their Shop in *Scarborough*; J. ROBINSON, next the *One Tun Tavern*, and T. HEATH, *Mathematical Instrument-Maker*, next the *Fountain Tavern* in the *Strand*; R. WILLIAMSON near *Gray's-Inn Gate*; and J. STAGG in *Westminster-Hall*. 1735.











T O

*The Right Honourable Sir CHARLES WAGER, KNT.  
First Lord Commissioner of the Admiralty; Admiral of the White  
Squadron; and Master of the Trinity-House, &c.*

*The Right Honourable ARTHUR ONSLOW, Esq; Speaker  
of the Honourable House of Commons; and Treasurer of the Navy, &c.*

*Sir JOHN NORRIS, Admiral of the Red Squadron.*

*Sir GEORGE WALTON, Admiral of the Blue Squadron.*

*Sir HANS SLOANE, Bart. Pr. Col. Med. Med. Reg. and  
President of the Royal Society.*

*EDMUND HALLEY, L L D. Royal Astronomer of  
Greenwich.*

*RICHARD BRADLEY, M. A. Savilian Professor of the  
Mathematics in Oxford.*

*NICHOLAS SANDERSON, L L D. Lucasian Profes-  
sor of the Mathematics in Cambridge.*

*ROBERT SMITH, L L D. Plumian Professor of the  
Mathematics in Cambridge.*

*The Honourable Sir THOMAS HANMER, Bart.*

*The Honourable WILLIAM CLAYTON, Esq;*

*Commissioners appointed by Act of Parliament, for the Discovery of the  
Longitude at Sea, and for examining, trying, and judging of all  
Proposals, Experiments, and Improvements relating to the same.*

GENTLEMEN,

**W**E beg leave, in the most respectful manner, to lay before  
You, *An easy and sure Method of ascertaining the Lon-  
gitude, or Difference of Meridians at Sea, within a  
Degree of a Great Circle, or sixty Geographical Miles, by  
means of certain Instruments contrived for that Purpose; the De-  
scription whereof we think proper to exhibit in this public manner, in  
order*

order to disappoint the Intentions of some Persons, who are disposed, on all occasions, to assume to themselves the Credit of other Men's Inventions ; as well as to prevent the Trouble and Inconvenience that might arise from such a *Pretence* of their having *hit* on the same *Discovery*.

We are not insensible, that a *Proposal* of *this kind* is attended with many *Difficulties* and *Discouragements* : The various *Idle Schemes* and *Chimerical Projects* that have been offered as *Discoveries* of the *Longitude*, have so much prejudiced Men's Minds against all Propositions of this sort, and brought so much Disgrace on the Projectors, that every *Attempt* to solve this *valuable Problem*, is now ridiculed as the effect of a weak, or a distempered Brain : The Thing itself has been so long the *Reproach of Art*, and every *Essay*, how promising soever, has hitherto proved so *unsuccessful*, that the greatest Part of Mankind look on it as an *Impossibility* ; for which Reason, we expect, what we say on this Subject, will be treated, by many Persons, with Ridicule and Contempt.

However, we shall endeavour to remove this Prejudice, by shewing, that the *Discovery of the Longitude at Sea*, is neither *impossible*, nor *impracticable*.

With regard to it's *Possibility*, Mathematicians are well enough satisfied in that Point ; more especially, the *Method* we are about to *propose*, and hope to render *practicable*, has long been approved of, and recommended by the best Astronomers, *as true in Theory, tho' very difficult in Practice* ; which we could readily make appear ; by several Testimonies in the *Philosophical Transactions*, and *elsewhere* ; but we shall content ourselves, at this Time, with quoting a Passage or two, from the late Reverend Mr *Flamsteed*, and the present Royal Astronomer of *Greenwich*, the Learned Dr *Halley*, who are not more universally, than deservedly, celebrated for their consummate Knowledge and Skill in these Affairs.

Mr *Flamsteed*'s Words are these ; (*Phil. Trans.* No. 151. p. 302.)  
 “ *The Eclipses of Jupiter's Satellites have been esteemed, and certainly*  
 “ *are a much better Expedient for the Discovery of the Longitude,*  
 “ *than any yet known, by reason that they happen frequently ; and are*  
 “ *easily observable with a Telescope of twelve Foot, or for need, with*  
 “ *one of Eight.*

Dr *Halley*,



Dr Halley speaking of the Method that the Royal Academy at Paris used, for settling the Geographical Situation of Places in France, says, (*Phil. Trans.* No. 214. p. 237.) “ *The Method they have used to determine the Longitude of their Places, is by the Observations of the Eclipses of the First Satellite of Jupiter, which they find almost instantaneous, and with good Telescopes, discernable, almost to the very opposition of Jupiter to the Sun; and it may be said, that this Account of the Longitudes observed, has put it past doubt, that this is the very best way, could portable Telescopes suffice for the Work: And could the Satellites be observed at Sea, a Ship at Sea might be enabled to find the Meridian she is in, by the help of the Tables Monsieur Cassini has given us in this Volume, discovering with great exactness the said Eclipses, beyond what we can yet hope to do by the Moon, tho’ she seem to afford us the only Means practicable for the Seamen. However, before Sailors can make use of this Art of finding the Longitude, it will be requisite that the Coast of the whole Ocean be first laid down truly; for which Work this Method by the Eclipses of Jupiter’s Satellites, is most apposite; and it may be hoped, that either a true Geometric Theory of the Moon may be discovered, by the Time the Charts are compleated, or else, that some Invention of Shorter Telescopes may suffice to shew the Eclipses of the Satellites at Sea*”.

Now, with respect to the *Practicability* of this Method, here the great Difficulty lies; *hic Labor hoc Opus!* In order, then, to render the same practicable at Sea, and serviceable to our Purpose, Two Things are principally required, *viz.*

*First*, In whatsoever Place the Ship is, to be capable of determining, there, the Time of the Day, or Night, to a sufficient Degree of Exactness.

*Secondly*, To be able to observe the Eclipses of the First Satellite of Jupiter, (or any other Phænomenon of the like kind) at Sea, the precise Time of whose Appearance can be known or predicted, at some other certain Place, or fixed Meridian.

As to the *first* of These, *viz.* The Way of finding the true Time of the Day, or Night, at the Place where the Ship is; altho’ most of the Writers on this Head, have taken it for granted that the Thing is very easy, yet, we apprehend, it cannot be obtained sufficiently exact, by any of the common Methods practised at Sea: One



of the best, and most approved, is that by the *rising of the Sun*, or a *fixed Star*, proper Allowance being made for Refraction, &c. And this needing no Instrument, would, no doubt, be very *easy*, and come near enough the *Truth*, if this *Appearance* could be *accurately* observed, as *often* as need should require: But this we are well assured is not to be done, by reason, that such *accurate* Observations can *rarely* be made, for *want* of a clear, perfect, and distinct *Horizon*. Wherefore, that we might obtain this *Requisite* with greater *Certainty*, and more *Frequency*, we contrived a *New Instrument*, whereby we are enabled, with much Facility, to take the *Altitudes* of the Sun and Stars at Sea, *without* an *Horizon*, to less than Five Minutes, and consequently to determine the *Latitude* of the *Place*, and the *Time* of the *Day*, or *Night*, at Sea, sufficiently *exact* for all the Purposes of Navigation; especially, if the *Height* of the Sun, or Star, be taken, to answer the *last* Intention, when it is at such an *Elevation*, as to have little or no *Refraction*; and is likewise *near* the *Prime Vertical*, for then it's *Altitude* is *changed* most sensibly, and considerably, in a very *small* space of *Time*.

This INSTRUMENT we shall now describe; and tho' it may be composed of any proper *Materials*, and of any *Radius*, yet, we judge, it will be most *convenient* for *Use*, at *Sea*, to make it a *Sextant* of *Brass*, cast in the *Form* exhibited by the *Scheme*; (See *Fig. 1.*) Let the *Radius* CA, of it's greatest *Arch* AB, be twelve Inches, (or thereabouts) which *Arch* is *graduated* only into single *Degrees*: The outermost *Edge* thereof must be curiously divided, or cut down, into two Hundred and forty fine *Teeth*, equal to, and at an exact Distance from, each other; of which, there will consequently be *four* in the space of *one* Degree: On the *Center* of this *Arch* C, is suspended upon an *Axis* that turns in *Pewet* Holes, a strong *Label*, or *Pendulum* of *Brass*, C D E F G, fifteen Inches long, which is *elevated* a little above the *Surface* of the *Sextant*, by means of a *Roller* fixed to it, which runs on the *lesser* *Arch*, *m n*, in order to avoid *Friction*, as much as possible, in it's *Vibration*: The *upper* Part of this *Pendulum* CD, is made in the *Form* of a flat *Ruler*, of the length of nine Inches; the *lower* Part of it, D E F G, is a *Circle*, six Inches in Diameter, about one Third of whose Area, or the *Segment* thereof, *x y z*, lying directly over the great *Arch* of the

the



the Sextant, is left *open*, that the Degrees thereon graduated may appear thro' it; and the *Chord* of this Segment  $\propto z$ , has it's thickness filed away, or sloped down, to a *Bevil* or *Chamferd* Edge, which is made *circular*, so that it may *apply* close to the said graduated Arch A B. The remaining *Part* or *Segment* of this Circle, E G F, is filled up with solid Brass, to give it a sufficient weight. Each *Quadrant* of the *Rim*, or *Periphery* of this Circle D E F G, is divided and numbered into sixty *equal Parts*, or *Minutes*, like a Dial-Plate: At the *Center* of this Circle  $p$  is placed, in a proper manner, a *Pinion* of sixteen Leaves, exactly proportioned to the Teeth of the great Arch, in which it plays freely, and turns *once* round precisely, whilst the Label, or Pendulum, passes over the space of *four* Degrees: This Pinion carries round with it an *Index*, or *Hand*, I, fixed upon it's *upper Part*, which, in it's Revolution, *marks*, or *points to*, the *Minutes* engraved on the *Periphery*, or Dial-Plate aforesaid; the Degrees being *shewn*, or *cut*, at the same Time, on the Arch of the Sextant, by a *right Line*, (drawn for that Purpose upon the Slope, or Chamferd Edge, from the Center of the circular Part of the Label, or Pendulum) whilst it hangs *perpendicular* to the *Horizon*, which it will do most constantly and exactly, notwithstanding the small Friction occasioned by the Pinion, and the Axis on which it turns; provided the Instrument be fixed in a vertical Plane, with it's Arch downwards, in the Time of Observation.

From what has been said, it is easy to perceive, that an Instrument thus formed, ought to be held, when it is made use of, as *steady* as possible, lest the Pendulum vibrate so much, as to cause a great Uncertainty, or Error, in the Angle to be measured: And here we must acknowledge, a considerable *Difficulty* occurred in this Matter; for, if plain Sights, or a Telescope in the *ordinary* Way, were fixed on one of the Radii of this Sextant, with it's Object-Glass towards the Center, and it's Eye-Glass next the Arch, it will be necessary to *elevate* the Arch, and consequently the whole Instrument above the Eye, in such a manner, as to put the whole Body of the Observer into a most irksome and unsteady Posture; by reason, that the Arms must be extended upwards, and the Head reclined backwards, in order to view an Object of any considerable Altitude: In such an *uneasy* Position, it is scarce possible to hold any Instrument so *steady* as is requisite, especially

on *Skip-board*, which any one may be readily convinced of that is disposed to make the Trial: Wherefore, we found it would be absolutely necessary to *contrive* some *other* Method, whereby, an Observer at Sea might be enabled to hold this Instrument with less *Uneasiness*, and more *Steadiness*; and this we effected in the following manner.

Instead of a Refracting Telescope to be placed on it's Radius, as has been usual, we devised a *New Instrument*, which for *Distinction* sake, and upon account of the *singular Use* we design to make of it in Astronomical Observations, we shall take the liberty to call an *Astroscope*. An *Astroscope* is thus formed.

In lieu of an Object-Glass, let there be made a *triangular Glass-Prism*, one *Face* whereof is a *Segment*, or *Portion* of the Convex Surface of a *Sphere*, whose Radius is nearly one half of the Length of the designed Instrument; and the two other *Faces* Plane-Quadrilateral Figures, three of whose *Sides* are *Rectilinear*, and the fourth *Side*, an *Arch* of a Circle: If the *Subtense* of the Arch be considered as one Side, instead of the *Arch* itself, then, one of the said Faces will be a *Square*, and the other (which we shall call it's Base) a *Parallelogram*, whose Length is to it's Breadth, in a subduplicate *Ratio* of Two to One. The *Angle* of the Prism in which these Plane Faces *meet*, must be *Forty-five* Degrees exactly; and then, if we imagine a Plane to pass through the Periphery which terminates the spherical Face, it will be perpendicular to, or make a *Right Angle* with, the square Face; and be *inclined* to the Base, or Parallelogram, in an Angle of *Forty-five* Degrees.

In one End of a brass Tube we fix a *Convex-Lens*, or *Eye-Glass*, of a shallow Charge, and a great Breadth; and at the other End, the *Prism* thus formed, with it's Convex Face turned *towards* the Eye-Glass, in such a manner, that the *Axis* of the Tube passes through the *middle* of it, at right Angles, and inclined to the *Base*, or *Parallelogram* of the Prism, in an Angle of *forty-five* Degrees; then will the *other* Plane Face, or Square, of necessity, lie *parallel* to the said Axis; directly over which, to give a Passage to the Rays of Light into this Instrument, a circular *Hole*, or *Aperture*, of a proper Magnitude, is cut thro' the Side of the Tube.

Those



Those who are skilled in Optics will readily perceive, that if the Rays of Light which flow from any *one Point* of an Object vastly distant, be considered as *parallel* to each other, at their Incidence upon the outermost Face of the Prism, and pass through it at *Right Angles*, they will be all *reflected* at it's Base, in such a manner, as to proceed in Right Lines *parallel* to the Axis of the Tube, till they arrive at the Convex Face, where they will, at their Emergence, be *refracted*, so as to *converge* towards a *Point*, nearly distant therefrom, by the Diameter of the Sphere to which the said Convex Surface was ground, and will *there* form a distant *Image* of the Object; which *Point* must therefore be the common *Focus* of the Prismatic-Object-Glass and the Eye-Glass; where two *Hairs* are to be placed at Right Angles to each other, intersecting mutually in the Axis of the Tube.

By an *Astroscope* thus formed, this peculiar Advantage is obtained, that we are not obliged to *elevate* it, or hold it *above* the Head, in a troublesome Position, in order to view any Object by it; for it is evident, from it's Construction, that the whole Tube, in the Time of Observation, must be *depressed* below the Eye, till it's Axis lie in such a Situation, as to be *perpendicular* to a Right Line drawn to it, or imagined to be so, from the Object to be observed; for then the Image of that Object will be distinctly seen by an Eye looking upon it through the Eye-Glass: And here it is to be noted, that all Objects will appear in this *Astroscope*, *Erect*, as in a Day-Telescope, but *inverted* with regard to *Right* and *Left*.

On *each* of the outermost *Radii* of our Sextant CA and CB, or parallel thereto, we place an *Astroscope*, with it's Eye-Glass towards the *Center*, and the Prismatic-Object-Glass towards the *Arch*: And thus the whole *Instrument* will be *finished*, and *adapted* for Observation, or taking Altitudes at Sea, or Land, *without* an *Horizon*. We shall in the next Place explain the

#### MANNER of USING it.

Let the *Observer*, either sitting or standing, hold the *Instrument* in *both* his Hands, with it's Arch *downwards*, in the same *vertical* Plane with the *Object*, and placing one Eye to that *End* of the

C

*Astroscope*

*Astroscope* O, which is next the Center, let him *elevate* and *depress* the whole *Instrument*, till the Object becomes *visible*, or *appears* at the *Interfection* of the Hairs, in the *Focus* of the *Astroscope*; upon which it is to be kept as *steady* as possible, till the *Pendulum* has nearly finished it's *Vibration*, or till it's *Motion* is almost ceased. In this the *sole* *Difficulty* lies, which will easily be overcome by a little *Custom* and *Practice*; so that a Person some time *accustomed* to make *Observations* with it, on *Skip-board*, will be able to hold it so *steady*, that the *Vacillation* of the *Pendulum* will *seldom* cause an *Uncertainty* of more than three or four *Minutes*, in the *Angle* to be taken: And if the *Motion* of the *Ship* should be so *great*, at some times, as to make the *Index* *vibrate* more than is here mentioned, yet the *Extremes* of that *Vibration* may be *noted*, and the *mean* *Number* will be that which is required.

By the *Astroscope*, if it be made (as it should be for this Use) to take in an *Area*, or *Field* of seven or eight *Degrees*, an Object may be readily found in this manner, and brought to the *Interfection* of the Hairs in it's *Axis*; the *Pendulum* then settling itself *perpendicular* to the *Horizon*, may be stopt there by the *Finger*, or a *Catch* for that Purpose; and the *Degrees* and *Minutes* shewn thereby, will give us the *true* *Altitude* of the Object, *quam proximè*, in case that *Astroscope* was made use of which is fixed on the *Radius* C A, drawn from the *Center* C to A, the *beginning* of the *Degrees* graduated upon the *Arch*: But if the *other* *Astroscope* K L is used, (which will be *necessary* when the Object is *elevated* more than sixty *Degrees* above the *Horizon*) then the *Pendulum* in it's *perpendicular* *Situation*, will mark the *Degrees*, and the *Index* will shew the *Minutes* of the Object's *Distance* from the *Zenith*.

#### DEMONSTRATION.

LET S represent any Object seen in the manner before described, at the *Interfection* of the Hairs f, in the *Focus* of the *Astroscope*, by the Eye of an Observer placed at O; draw the Right Line S q, described by a Ray flowing from the *Center* of the Object, and passing through the middle of the outermost Face of the *Prism*, at Right Angles, to the Point q in it's Base, where it will be reflected, in such a manner, as to become coincident with the *Axis* of the *Astroscope*,  
making



making the Angle  $Sqf$ , a Right one (by the Construction of the Prism already given). Continue the Line  $Sq$  till it meet the Radius of the Sextant  $CA$  in  $R$ , then will the Angle  $SRC$  be likewise Right, because  $RC$  is parallel to  $qs$  (by hypothesis). Through the Point  $R$ , draw the Right Line  $HD$ , perpendicular to the Plumb-line of the Pendulum  $CD$ ; which will therefore be an Horizontal Line, and the Angle  $HRS$ , by consequence, is the true Altitude of the Object  $S$ . Now we are to prove, that the Angle  $RCD$ , whose Measure is the Arch  $Ap$ , cut by the Pendulum or Plumb-line  $CD$ , produced to  $p$ , is equal to the aforesaid Angle  $HRS$ , or the true Altitude of the Object. By the thirty-second Proposition of the first Book of Euclid, the outward Angle  $HRC$ , that is, the Angle  $HRS +$  the Angle  $SRC$ , is equal to the two inward and opposite Angles taken together, viz.  $RCD + RDC$ ; but the Angle  $SRC$  is equal to  $RDC$ , for they are both Right (by Construction as was shewn above); therefore the Angle  $HRS$  is also equal to the Angle  $RCD$  (Euclid, Axiom 3.) Q. E. D.

In like manner it may be shewn, that the Angle comprehended between the Radius  $BC$  and the vertical Line of the Pendulum  $CD$ , will be equal to the Zenith-Distance of any Object, seen or observed by means of the other Astroscope  $KL$ , which lies parallel to the Radius  $CB$ , drawn from the Center  $C$  to the End of the Degrees on the Arch at  $B$ .

There is another Manner of observing the Sun's Altitude by this Sextant, when He shines clear, which is thus: Let the Observer hold the Instrument as before, in the same vertical Plane with the Object, it's Arch being downwards, and the Face of it turned towards him; then let him elevate and depress it, till a Convex Lens fixed upon one of it's Radii, form a bright Spot, or Image of the Sun, at the Intersection of two Lines drawn on a Plane, that is placed in it's Focus, at Right Angles, to the Axis of the Lens; and the Pendulum hanging perpendicular at the same time, to the Horizon, will shew the Degrees and Minutes of the Sun's Altitude, or his Distance from the Zenith, in the same manner as before.

It is scarce needful to mention, that if instead of a Sextant, the Instrument be made a Quadrant, one Astroscope placed on either of the Radii, will suffice to observe Objects at all Degrees of Altitude. We may likewise add, that for common Use at Sea, 'twill be sufficient



cient to *graduate* this *Instrument* to every *five Minutes*, which may be done *without* any *Teeth*, *Pinion*, or *Index*; for the *Bevil*, or *Chamferd Edge* of the *Pendulum*, which *cuts* or *applies* to the *Degrees* of the great *Arch*, may be *divided* after the manner of *Nonius*, so as to *show* the *Angle* to every *five Minutes*: And this *Method* will render the *Instrument* very *cheap*, as well as extremely *simple*, and sufficiently *accurate*.

Having given the *Description* and *Manner* of *using* this *Instrument*, it may be proper to enumerate some of those *Advantages*, upon account of which, it is *preferable* to any other that has hitherto been *invented* for taking the *Altitudes* of *Objects* at *Sea*.

The *first* Advantage, and not the *least*, results from the very *Nature* and *Construction* of this *Instrument*, whereby we are *enabled* to find the *Latitude* at *Sea*, much *more frequently* than by any other; a thing of such *extraordinary* Use in *Navigation*, that it is, in the Opinion of many Persons, as much wanted and desired, for the *Safety* of *Ships* and *Preservation* of *Mens Lives*, as the *Longitude* itself: Now, it is but too well known, by long and sad *Experience*, that the very *best Instruments*, if they *require* an *Horizon*, are often rendered *useless* by the *want* of it, when the *Need* of them is greatest, and the *Danger* most imminent; as for instance, in coming in with the *Land* or *Coast* of this *Island*, in *Voyages* from the *East* and *West Indies*, &c. for in our *uncertain* Climate 'tis *rare* to have a clear and perfect *Horizon*, and that too must be seen when the *Sun* is upon the *Meridian*, otherwise 'tis of no *Service* for this *Purpose*; by which means a very able *Commander* assures us, he has been disappointed of obtaining the *Sun's Meridian-Altitude*, from one *Day* to another, for several *Weeks* together, and this in no wise occasioned by tempestuous *Weather*; for *Seamen*, as the ingenious *Mr Hadley* observes, (*Phil. Trans.* No. 430. p. 167) "are much oftner sensible of this [*Impediment*] in calm *Weather* than in rough." Now the *Necessity* of seeing the *Horizon*, is an *Inconvenience* we have intirely removed, insomuch, that if the *Place* of the *Sun* in the *Heavens* is but visible, as He shines through a *Cloud*, tho' so faintly as to give no *Shade*, yet an exact *Observation* may be made, and his true *Altitude* obtained, by means of our *Instrument*: But we have yet a much greater *Benefit* by it; for tho' the *Sun* should not be seen  
at



at *Noon-Day*, it may, and often does happen, that the Heavens are *clear* and *serene* at some time of the *Night*: And since, at *all Hours*, there will be *one* or *other* of the most noted of the *fixed Stars*, upon, or near the *Meridian*, the *Opportunities* of taking their *Altitudes*, and consequently of finding the *Latitude* at *Sea*, will be as *frequent* as can be desired.

The *second* Advantage of our *Instrument* is, that we are enabled to obtain the *Altitudes* of the *Sun* and *Stars* at *Sea*, more accurately than by any other; and this is derived from the same excellent *Property* of it's *Usefulness* without an *Horizon*. With regard to the *Stars*, we need not say how altogether *insufficient* the Instruments hitherto used, are for *this* Purpose; and in taking *Altitudes* of the *Sun*, with the *common* Quadrants, the *Error* that almost constantly arises from the *Indistinctness*, *Obscurity*, and *Uncertainty* of the *sensible Horizon*, when looked at as an *Object*, is much greater than is generally believed by those that have made no Experiments to ascertain it: However, that the *Error* is *considerable*, we are fully convinced, not only by the *Reason* of the *Thing*, but also by the *Experience* of a very skillful and judicious Navigator, Captain *Christopher Middleton*; to whom the Public is indebted for many curious and useful Observations, made in his Voyages to *Hudson's Bay*. This Gentleman (whose *Example* it is to be wished *other Commanders* of Ships would follow) has compared several *Altitudes* of the *Sun*, taken on *purpose*, with very accurate Instruments, in *still Water*, both *with*, and *without* an *Horizon*; and from all his *Trials*, he constantly found a *Difference* between them, and discovered an *Error* to be introduced from the *Uncertainty* of the *Horizon* only, which frequently amounted to *thirty* Minutes, or more, and seldom to so little as five: This *Imperfection* has no place in our *Instrument*, which is not *subject* to the least *Error* on this *Account*; and the greatest that can happen thro' the *Unsteadiness* of the *Pendulum*, will seldom be so much as *five* Minutes, in the Hand of an *Observer* who has *accustomed* himself, for a little time, to the *Use* of it on *Ship-board*.

A *Method* of taking *Altitudes* at *Sea* to so great a Degree of *Exactness*, is of such *Advantage*, not only in finding the *Latitude* of the *Place*, but likewise for solving many *other Problems*; more particularly, that of obtaining the true *Time* of the *Day* or *Night*,

D

which



which has hitherto been so difficult to accomplish, with sufficient Certainty; that Mr Hodgson, in his excellent *System of the Mathematics*, Vol. 1. p. 383. says, “ *Whoever can contrive any way to take the Height of the Sun, or any fixed Star, at Sea, to one or two Minutes, may fairly be entituled to a Share of the Discovery of the Longitude, and ought to have a proportional Reward.*”

With respect to the Accuracy of our Instrument, we shall, in this Place, take notice of another Property in which it excels, and that is, the manner of it's Graduation. It has hitherto been very difficult, in Instruments of so small a Radius as this, to graduate them into Parts minute enough for very accurate Observations, without much Confusion: This Defect we have remedied, by a new Method of dividing the small Space of a Degree, more exactly, minutely, and distinctly, than can be done by any of the common ways in Use: Hence it is that our Sextant is exceeding accurate, tho' the Radius be very small; and the Minutes are as visible, and as easily distinguished here, as in other Instruments whose Size is ten times as large.

A third Advantage of this Instrument is, that we can obtain the Altitudes of the Sun and Stars, at Sea, more easily than by any other. Now this Facility arises from our having only one Object to regard, which we can find most readily by our *Astroscope*; whereas, those who make use of an *Horizon*, have this Inconvenience, that they must, of necessity, see two Objects together, at one and the same time; but one of these Objects, to wit, the *Horizon*, tho' it be ever so clear and perfect, is frequently lost by the Surge of the Sea, or intercepted by the Rising of the Billows between It and the Observer's Eye; and all Instruments whatsoever, that require an *Horizon*, are unavoidably subject to this great Obstruction; for it is not, simply, the Motion or Unsteadiness of the Observer's Hand, as some have imagined, which, in this Case, disturbs the Observation, so much as the Interposition of the Waves of the Ocean, or the Swelling of the Sea before-mentioned, that really and absolutely deprives us of the Sight of the *Horizon*, for some time, permitting it to return only by Fits, as it were, and snatching it again from our View, on a sudden. To these Interruptions our Instrument is not liable, which must certainly recommend the Use of it, and render it acceptable to such as have experienced how tedious, troublesome,



and difficult it is, to *adjust* the *Sights*, or *Vanes* of the common Quadrants, for taking Altitudes on Ship-board.

The *fourth*, and *last* Advantage, that we shall at present mention, of this *Instrument*, is it's *Usefulness* at *Land*, as well as at *Sea*: Now many Persons who use the Sea, will think, perhaps, they receive no Benefit by this Property of it, but a little Consideration will convince them of the contrary; for it has already been hinted, of how great Service it would be, to have the *Coast of the whole Ocean truly laid down*; and we may reasonably hope, that an *Instrument* so *portable*, and not at all *cumbersome*, so *accurate*, and not subject to *warp*, or *alter* with the Weather, in a word, so *easy*, and even *pleasant* in the manner of it's *Use*, will be sufficient of itself, to induce the Commanders of Ships, and other curious Persons, to take the *Meridional Altitudes* of the *Sun* or *Stars*, at all the *Places* and *Ports* where they come; by which means, they might soon furnish us with great *Numbers* of exact, and useful *Observations* for correcting and ascertaining the *Situation* of *Places* in *Maps* and *Sea-Charts*, to the great Improvement of *Geography* and *Navigation*; to which, if they would also be pleased to add the *Observations* of the *Eclipses* of *Jupiter's Satellites*, which they may with great Ease and Pleasure do, by means of the *Telescope* hereafter-mentioned, we might soon expect to see those *Arts* advanced to their highest Perfection.

We now proceed to the *second Thing* proposed, *viz.* to be able to observe the *Eclipses* of the *First Satellite* of *Jupiter* (or any other Phenomenon of the like kind) at *Sea*, the *precise Time* of whose Appearance can be *known* or *predicted*, at some other certain *Place*, or fixed *Meridian*.

To this End, we shall here describe the *manner* in which a *Telescope*, easily *manageable* on Ship-board, and altogether *sufficient* for this Purpose, may be formed.

Let there be made a *Tube*, or hollow *Cylinder* of Brass, *ABCD*, (*vid. Fig. 2.*) about *four Foot* long, and *four Inches*, or somewhat more, in *Diameter*, dyed as *black* as possible on the Inside. At one End of this Tube, a metalline *Speculum*, *EF*, spherically *concave*, and *polished* with the utmost Care, whose *focal Distance* is *forty-eight Inches*, or thereabouts, must be fixed, so that it's

Axis

Axis may *coincide* exactly with that of the Cylinder : Near the other End of the Tube, which is open, a brass *Arm*, or *Handle* H G, must descend into the middle of it's Cavity, which may be moved *nearer* to, or *farther* from, the great Speculum, as occasion requires, by means of a *Slider*, to which it is fixed at the Side of the Tube.

To the *End* of this *Arm* is cemented a small *oval Plane*, of polished *metal*, or rather a *Triangular Prism* of Glass,  $pqr$ , whose *uppermost* Angle  $r$ , is a *Right one*, and the other two are each exactly *Forty-five Degrees* : The *Faces* of the Prism, which meet in the *Right Angle*, are exactly *square* ; and the *third Face* is a *Rectangular Parallelogram*, whose *Breadth* is to it's *Length*, as 1 to the square root of 2. This *Prism* must be placed in such a manner, that a *Ray* reflected from the *Concave Speculum*, may pass thro' the middle of the square Face  $pr$ , at *Right Angles*, but *inclined* to the *Parallelogram* in an Angle of *Forty-five Degrees*, and it's *Distance* from the *Concave Surface* of the Speculum E F, such, that the *Rays* reflected from the *Concave*,  $xm$ ,  $zn$ , after their *second Reflection* at the *Base* of the Prism, may *meet* or *unite* in the *Inside* of the Tube, at  $i$  ; that is, so as the *Distance* of the *Focus*  $i$ , from the reflecting *Surface* of the Prism, and of that from the *Concave Speculum*, may be equal to the *Focal Distance* of the *Concave Speculum* itself. In the Side of the Tube, an *Aperture* or *Space* is cut open, to give a *Passage* to the reflected *Rays*, which are conveyed to the Eye through three *Convex Eye-Glasses*, placed in a small brass Tube, S T O, at *Right Angles* to the *Great one* : The *Focal Length* of the Lens next the Eye, is about *one Inch*, and as *broad* as may be : The other two Eye-Glasses are exactly a-like, and the *Focal Length* of each, about two and a half, or three *Inches* : The *Telescope* thus formed, represents all Objects *Erect*, and they will appear in it as *bright*, as *distinct*, and as *much magnified*, as in the best *refracting one* of sixteen Foot, charged with a *four-Inch* Eye-Glass ; and consequently the *Satellites* of *Jupiter*, will be as plainly and clearly discerned in *one*, as in the *other*. Now we have already shewn, by the *Authorities* we quoted, that if such a *Telescope* could be made *useful* and *manageable* on Ship-board, it would not only *suffice*, but also be the *very best way* to determine the *Longitude*, or *Difference of Meridians* at Sea ; but hitherto no *Method* has been *discovered* of making *Telescopes serviceable* at  
Sea,



*Sea*, in celestial Observations, when they *magnify* in any considerable Degree. The *Cause* of this must be attributed, either to the supposed *Impracticability* of finding an Object thereby *readily*, or else to the *Difficulty* of keeping it in *View* within the *Telescope*, when it is found, by reason of the rolling Motion of the Ship.

As to the *first Impediment*, which is indeed the *greatest*, we have contrived a Method, whereby it is intirely removed, *viz.* by placing an *Astroscope*, such as we have before described, at *Right Angles*, to the *Axis* of the great *Telescope*, adjoining to, and of the same Length with, the small *Tube* which contains the three *Eye-Glasses*: By means of this *Astroscope*, which takes in a *Field* of seven or eight Degrees, any Object may be found most *readily*, and brought near to the Intersection of the Hairs, in it's Focus, at which Time the *Eye* may be removed, with Ease, to the *Eye-Glass* of the great *Telescope*, (forasmuch as they are close to one another); and the Object will then be *visible* in that also: Those who have *accustomed* themselves to look with *both Eyes* at once, which it is *easy* to do, may place the *Eye-Piece* of the *Astroscope*, at a *Distance* from the *Eye-Piece* of the *Telescope*, equal to *that* between the two *Eyes* of the Observer, after the manner that is practised in a *Binocle-Telescope*; so that while he sees the Object in the *Astroscope* with *one Eye*, he may likewise view it in the *Telescope* with the *other Eye*.

Now, as to the *second Difficulty* of retaining the Object in *View*, without *losing* the *Sight* of it after it is found, We need only observe, that the *Field* of the Great *Telescope* will be a *whole Degree*, or thereabouts, which is a considerable Space; and also that the *Position* in which this kind of *Telescope* must of necessity be *beld*, in the Time of Observation, will, of itself, *contribute* very much to the *Stability* required; for the open *End* of the great *Tube* will be very *little above* the *Eye*, and the remaining *Part* of it will lie *intirely below* it, passing along the right Side, or under the right Arm; which is a *Situation* most *advantageous* for supporting, managing, and directing it, with little Trouble or Uneasiness. To this we may likewise add, that it is not in the least *cumberfome* or *unweildy*, either from it's *Length*, or it's *Weight*, which need not be at most, above *fourteen Pounds*; besides, it is *easy* to *support* the lower End, in which the great *Speculum* lies, by means of

E

a *Suspen-*



a *Suspensory* from some Part of the Body, if need require it, so that the Hands shall feel very little of it's Weight, and be at intire *Liberty* to govern and adjust it.

The Learned Dr *Halley* (in the Appendix to the second Edition of *Street's Caroline Tables*) assures us, " He had found, it only needed  
" a little *Practice*, to be able to manage a five or six Foot Telescope,  
" capable of shewing the *Appulses*, or *Occultations* of the fixed Stars by  
" the Moon, on Ship-board, in moderate Weather".

Now 'tis evident, that the Telescope we have described, takes in a larger Field, and may be managed with much greater Ease than a *refracting* one of five or six Foot, or even than one of four Foot; for in ours, there will never be any occasion to recline the Head, and extend the Arms aloft, as 'tis necessary when we look upwards at an Object, with a *refracting* Telescope; which manner of Observing is not only tiresome, but likewise creates in the Observer so great an *Unsteadiness*, that he cannot, without much *Difficulty*, direct the Instrument so as to keep the Object in View for the smallest Space of Time.

Upon this Head we shall also cite the Authority of that ingenious Gentleman, Mr *Hadley*, before-mentioned, who tells us, (*Phil. Transf.* No. 430. p. 172.) " He has been informed, that an  
" Object may be kept in View without much *Difficulty*, even in pretty  
" rough Weather, through a [refracting] Telescope, magnifying about  
" ten times: Now as such Telescopes seldom comprehend an Area of  
" much more than one Degree in Diameter, or at most one Degree  
" twenty Minutes, it follows, that the Axis of the Telescope is always  
" kept within forty Minutes, at most, of the Object, and that is the  
" greatest Vibration of the Image above and below it".

Wherefore since our Telescope admits of as large a Field, and is less difficult to manage than those *refracting* ones, which have been found by Experience to be serviceable at Sea, we may very well venture to affirm, that a little Practice will render it easy for an Observer to hold our Telescope on Ship-board, so steady, that an Object once seen in it, will seldom be lost, or thrown out of it, by the ordinary Motion of the Ship; or if it should sometimes be so, it may quickly be recovered again, by the help of the *Astroscope*.

When this Telescope is not used, the Object-metal must be taken out of the Tube, and kept close shut up from the Air; and if it happen



happen to *soil* or *tarnish*, it may be *cleared* again easily, by rubbing it with soft Leather, or a Rag, and a little Spirit of Wine.

We have now shewn how the *Eclipses* of the *first Satellite* of *Jupiter*, (or any other Phenomenon of the like kind, such as the *Eclipses* of the other *Satellites*, the *Appulses* of the Moon to the fixed Stars, &c.) may be *observed* at *Sea*, with great *Certainty*, and much *Facility*; as likewise how the *true Time* of that Observation may be *obtained*, at the *Place* where the *Ship* is: It only remains, that we be able to *know* the *Time* when the *same* Appearance happens in some other *Place*, or fixed *Meridian*; for Example, at *London*; because, this also being ascertained, the *Difference* of the said *Times* converted into Degrees and Minutes of the Equator, will give the *Distance* of the *Meridians* of those two Places, or discover the *Longitude* at *Sea*. Now the *Times* when the *Eclipses* of the *first Satellite* of *Jupiter* happen under the *Meridian* of *London*, may be computed exactly by the *Tables* annexed.

We think it proper, before we conclude, to intimate of how great *Use* and *Benefit* a good *Time-Keeper* will likewise be, for ascertaining the *Longitude* of *Places* at *Sea*, in the *Intervals* between the *Observations* of these *Eclipses*: *Instruments* of that kind are now made in so great *Perfection*, that for the most part, they may be depended on for several Days together, without any *considerable* Error. However, since by the *Method* here proposed, we shall be furnished with frequent Opportunities of *correcting* and *adjusting* them, as well as of *discovering* how much their *Variation* amounts to, in the *Time* elapsed between one Observation and another, when they go too fast, or too slow; we shall consequently know their daily *Deviation* or *Error*, and in what manner to make a proper *Allowance* for it in our *Calculations*; by which means they will become as *useful* to us, for this Purpose, as if they had gone most constantly *true*, without any *Change* or *Alteration*; all which is so manifest and obvious, that we need not here enlarge upon it.

This Proposal, *Gentlemen*, of a Method for *Discovery* of the *Longitude* at *Sea*, we submit to your Consideration, as you have been constituted the proper *Judges* of it by the *Legislature*; who have also been pleased to declare, that such a *Discovery* would be of  
particular

*particular Advantage to the Trade of Great Britain, and an Honour to this Kingdom.*

We therefore hope, that an *Endeavour* to improve so beneficial and excellent an *Art*, as this of *Navigation*, and advance it to a higher Degree of Perfection, will meet with your *Approbation* and *Encouragement*.

*We are,*

*With the greatest Deference, and Regard,*

GENTLEMEN,

*Your most Obedient, and*

*Most Humble Servants.*

London, January the  
20th, 1734.



AB. I. Epochæ Conjunctionum Mediarum Primi Satellitis cum Jove,  
sub Meridiano Londinenfi.

An. Jul. Cur.	Conjunct. med.				Num. A.	Num. B.		An. Jul. Cur.	Conjunct. med.				Num. A.	Num. B.
	D.	H.	I	II					D.	H.	I	II		
1729	I	6	0	12	715	554		1745	I	7	55	8	63	205
1730	0	20	11	39	799	468		1746	0	22	6	35	148	119
31	0	10	23	7	883	382		47	0	12	18	3	232	33
32	0	0	34	34	967	296		48	0	2	29	30	316	947
33	0	9	14	38	52	215		49	0	11	9	34	400	866
34	I	17	54	41	136	133		50	0	I	21	I	485	780
1735	I	8	6	9	220	47		1751	I	10	I	5	569	698
36	0	22	17	36	305	961		52	I	0	12	33	653	612
37	I	6	57	40	389	880		53	I	8	52	37	738	531
38	0	21	9	7	473	794		54	0	23	4	4	822	445
39	0	11	20	35	557	708		55	0	13	15	32	906	359
1740	0	I	32	2	642	622		1756	0	3	27	0	990	273
41	0	10	12	6	726	540		57	0	12	7	3	75	191
42	0	0	23	33	810	454		58	0	2	18	30	159	110
43	I	9	3	37	895	373		59	I	10	58	34	243	24
44	0	23	15	4	979	287		60	I	I	10	I	328	938

TAB. II. Revolutiones Primi Satellitis Jovis in Mensibus.

<i>Januarii.</i>				Num. A.	Num. B.	<i>Martii.</i>				Num. A.	Num. B.
D.	H.	'	"			D.	H.	'	"		
1	18	28	36	0	5	1	4	12	23	14	155
3	12	57	12	1	9	2	22	40	59	14	159
5	7	25	48	1	14	4	17	9	35	15	164
7	1	54	24	2	18	6	11	38	10	15	168
8	20	23	0	2	23	8	6	6	46	16	173
10	14	51	36	2	27	10	0	35	22	16	177
12	9	20	12	3	32	11	19	3	58	16	182
14	3	48	48	3	37	13	13	32	34	17	186
15	22	17	24	4	41	15	8	1	10	17	190
17	16	46	0	4	46	17	2	29	46	18	195
19	11	14	36	4	51	18	20	58	22	18	199
21	5	43	12	5	55	20	15	36	58	18	204
23	0	11	47	5	60	22	9	55	34	19	208
24	18	40	23	6	64	24	4	24	10	19	213
26	13	8	59	6	69	25	22	52	46	20	217
28	7	37	35	7	73	27	17	21	22	20	221
30	2	6	11	7	78	29	11	49	58	20	225
31	20	34	47	7	82	31	6	18	34	21	230
<i>Februarii.</i>				Num. A.	Num. B.	<i>Aprilis.</i>				Num. A.	Num. B.
D.	H.	'	"			D.	H.	'	"		
0	20	34	47	7	82	0	6	8	34	21	230
2	15	3	23	8	87	2	0	47	10	21	235
4	9	31	59	8	92	3	19	15	46	22	239
6	4	0	35	9	96	5	13	44	22	22	244
7	22	29	11	9	101	7	8	12	58	22	248
9	16	57	47	9	105	9	2	41	34	23	252
11	11	26	23	10	110	10	21	10	10	23	257
13	5	54	59	10	114	12	15	38	46	24	261
15	0	23	35	11	118	14	10	7	22	24	265
16	18	52	11	11	123	16	4	35	58	25	270
18	13	20	47	11	128	17	23	4	33	25	274
20	7	49	23	12	132	19	17	33	00	25	279
22	2	17	59	12	137	21	12	1	45	26	283
23	20	46	35	13	141	23	6	30	21	26	287
25	15	15	11	13	146	25	0	58	57	27	292
27	9	43	47	13	150	26	19	27	33	27	296



TAB. II. Revolutiones Primi Satellitis Jovis in Mensibus.

<i>Aprilis.</i>				Num. <i>A.</i>	Num. <i>B.</i>	<i>Junii.</i>				Num. <i>A.</i>	Num. <i>B.</i>
<i>D.</i>	<i>H.</i>	<i>'</i>	<i>"</i>			<i>D.</i>	<i>H.</i>	<i>'</i>	<i>"</i>		
28	13	56	9	27	300	24	5	11	20	40	438
30	8	24	45	28	304	25	23	39	56	41	442
<i>Maii.</i>						27	18	8	32	41	446
0	8	24	45	28	304	29	12	37	8	42	450
2	2	53	21	28	309	<i>Julii.</i>					
3	21	21	57	29	313	1	7	5	44	42	455
5	15	50	33	29	317	3	1	34	20	42	459
7	10	19	9	29	322	4	20	2	56	43	463
9	4	47	45	30	326	6	14	31	32	43	468
10	23	16	21	30	330	8	9	0	8	44	472
12	17	44	57	31	335	10	3	28	44	44	476
14	12	13	33	31	339	11	21	57	20	45	480
16	6	42	9	31	343	13	16	25	55	45	485
18	1	10	45	32	348	15	10	54	31	45	489
19	19	39	21	32	352	17	5	23	7	46	493
21	14	7	57	33	356	18	23	51	43	46	498
23	8	36	33	33	361	20	18	20	19	47	502
25	3	5	9	33	365	22	12	48	55	47	506
26	21	33	45	34	369	24	7	17	31	47	510
28	16	2	21	34	373	26	1	46	7	48	515
30	10	30	57	35	378	27	20	14	43	48	519
<i>Junii.</i>						28	14	43	19	49	523
0	10	30	57	35	378	31	9	11	55	49	528
1	4	59	32	35	382	<i>Augusti.</i>					
2	23	28	8	36	386	0	9	11	55	49	528
4	17	56	44	36	391	2	3	40	31	49	532
6	12	25	20	36	395	3	22	9	7	50	536
8	6	53	56	37	399	5	16	37	43	50	541
10	1	22	32	37	403	7	11	6	19	51	545
11	19	51	8	38	408	9	5	34	55	51	549
13	14	19	44	38	412	11	0	3	31	51	554
15	8	48	20	38	416	12	18	32	7	52	558
17	3	16	56	39	420	14	13	0	43	52	562
18	21	45	32	39	425	16	7	29	19	53	567
20	16	14	8	40	429	18	1	57	55	53	571
22	10	42	44	40	433	19	20	26	31	54	575

TAB. II. Revolutiones Primi Satellitis Jovis in Mensibus.

<i>Augusti.</i>				<i>Num.</i>	<i>Num.</i>	<i>Octobris.</i>				<i>Num.</i>	<i>Num.</i>
<i>D.</i>	<i>H.</i>	<i>'</i>	<i>"</i>	<i>A.</i>	<i>B.</i>	<i>D.</i>	<i>H.</i>	<i>'</i>	<i>"</i>	<i>A.</i>	<i>B.</i>
21	14	55	7	54	580	31	9	59	5	70	758
23	9	23	43	54	584	<i>Novembris.</i>					
25	3	52	18	55	588	0	9	59	5	70	758
26	22	20	54	55	593	2	4	27	41	71	762
28	16	49	30	56	597	3	22	56	17	71	767
30	11	18	6	56	602	5	17	24	53	71	772
<i>Septembris.</i>						7	11	53	29	72	776
1	5	46	42	56	606	9	6	22	5	72	781
3	0	15	18	57	610	11	0	50	41	73	785
4	18	43	54	57	615	12	19	19	17	73	790
6	13	12	30	58	619	14	13	47	53	74	794
8	7	41	6	58	624	16	8	16	29	74	799
10	2	9	42	58	628	18	2	45	5	74	804
11	20	38	18	59	632	19	21	13	40	75	808
13	15	6	54	59	637	21	15	42	16	75	813
15	9	35	30	60	641	23	10	10	52	76	817
17	4	4	6	60	646	25	4	39	28	76	822
18	22	32	42	60	650	26	23	8	4	76	827
20	17	1	18	61	655	28	17	36	40	77	831
22	11	29	54	61	659	30	12	5	16	77	836
24	5	58	30	62	663	<i>Decembris.</i>					
26	0	27	6	62	668	0	12	5	16	77	836
27	18	55	42	62	672	2	6	33	52	78	840
29	13	24	18	63	677	4	1	2	28	78	845
<i>Octobris.</i>						5	19	31	4	78	849
1	7	52	54	63	681	7	13	59	40	79	854
3	2	21	30	64	686	9	8	28	16	79	859
4	20	50	6	64	690	11	2	56	52	80	863
6	15	18	41	65	695	13	21	25	28	80	868
8	9	47	17	65	699	14	15	54	4	80	873
10	4	15	53	65	704	16	10	22	40	81	877
11	22	44	29	66	708	18	4	51	16	81	882
13	17	13	5	66	713	19	23	19	52	82	886
15	11	41	41	67	717	21	17	48	28	82	891
17	6	10	17	67	721	23	12	17	4	82	897
19	0	38	53	67	726	25	6	45	40	83	900
20	19	7	29	68	730	27	1	14	16	83	905
22	13	36	5	68	735	28	19	42	52	84	909
24	8	4	41	69	739	30	14	11	28	84	914
26	2	33	17	69	744						
27	21	1	5	69	749						
29	15	30	29	70	753						



TAB. III. *Æquationes Conjunctionum Primi Satellitis cum Jove.*

Num. A.	Æquat. Conjunct. Adde.		Æq. Num. B.	Num. A.	Æquat. Conjunct. Adde.		Æp. Num. B.	Num. A.	Æquat. Conjunct. Adde.		Æq. Num. B.	Num. A.	Æquat. Conjunct. Adde.		Æq. Num. B.
	I	II			I	II			I	II			I	II	
0	39	8	15	128	12	7	26	256	0	1	31	384	11	52	26
4	38	12	16	132	11	27	26	260	0	0	31	388	12	37	26
8	37	16	16	136	10	47	26	264	0	1	31	392	13	23	25
12	36	21	16	140	19	9	27	268	0	3	31	396	14	11	25
16	35	26	17	144	9	31	27	272	0	7	31	400	14	59	25
20	34	30	17	148	8	45	27	276	0	12	31	404	15	48	24
24	33	35	17	152	8	19	27	280	0	19	31	408	16	38	24
28	32	40	18	156	7	44	28	284	0	28	30	412	17	30	24
32	31	45	18	160	7	10	28	288	0	38	30	416	18	22	23
36	30	50	19	164	6	38	28	292	0	50	30	420	19	15	23
40	29	56	19	168	6	7	28	296	1	3	30	424	20	9	23
44	29	3	19	172	5	37	28	300	1	17	30	428	21	4	22
48	28	10	20	176	5	8	29	304	1	33	30	432	22	59	22
52	27	16	20	180	4	41	29	308	1	50	30	436	22	55	22
56	26	23	20	184	4	15	29	312	2	8	30	440	23	53	21
60	25	30	21	188	3	49	29	316	2	28	30	444	24	51	21
64	24	38	21	192	3	24	29	320	2	51	30	448	25	49	21
68	23	47	21	196	3	1	29	324	3	15	29	452	26	48	20
72	22	56	22	200	2	40	30	328	3	40	29	456	27	48	20
76	22	5	22	204	2	20	30	332	4	6	29	460	28	48	19
80	21	15	22	208	2	1	30	336	4	34	29	464	29	49	19
84	20	26	23	212	1	42	30	340	5	3	29	468	30	50	19
88	19	37	23	216	1	25	30	344	5	34	29	472	31	51	18
92	18	48	23	220	1	10	30	348	6	5	28	476	32	53	18
96	18	0	24	224	0	58	30	352	6	38	28	480	33	55	17
100	17	14	24	228	0	47	30	356	7	13	28	484	34	57	17
104	16	28	24	232	0	36	30	360	7	50	28	488	35	59	17
108	15	42	24	236	0	26	30	364	8	27	27	492	37	1	16
112	14	57	25	240	0	18	30	368	9	6	27	496	38	5	16
116	14	13	25	244	0	12	31	372	9	46	27	500	39	8	15
120	13	30	25	248	0	7	31	376	10	27	27	504	40	11	15
124	12	48	26	252	0	4	31	380	11	9	26	508	41	15	14
128	12	7	26	256	0	1	31	384	11	52	26	512	42	17	14

TAB. III. Primæ Æquationes Conjunctionum Primi Satellitis cum Jove.

Num. A.	Æquat. Conjunct. Adde.		Æq. Num. B.	Num. A.	Æquat. Conjunct. Adde.		Æq. Num. B.	Num. A.	Æquat. Conjunct. Adde.		Æq. Num. B.	Num. A.	Æquat. Conjunct. Adde.		Æq. Num. B.
	I	II			I	II			I	II			I	II	
512	42	17	14	640	70	26	3	768	77	40	0	896	61	48	6
516	43	19	14	644	71	3	3	772	77	29	0	900	61	2	7
520	44	21	13	648	71	38	3	776	77	18	0	904	60	15	7
524	45	23	13	652	72	11	2	780	77	6	0	908	59	28	7
528	46	25	13	656	72	42	2	784	76	51	1	912	58	39	8
532	47	26	12	660	73	13	2	788	76	34	1	916	57	50	8
536	48	27	12	664	73	42	2	792	76	15	1	920	57	1	8
540	49	28	11	668	74	10	2	796	75	56	1	924	56	11	9
544	50	28	11	672	74	36	1	800	75	36	1	928	55	20	9
548	51	28	11	676	75	1	1	804	75	15	1	932	54	29	9
552	52	27	10	680	75	25	1	808	74	52	1	936	53	38	10
556	53	25	10	684	75	48	1	812	74	27	1	940	52	46	10
560	54	23	9	688	76	8	1	816	74	1	2	944	51	53	10
564	55	21	9	692	76	26	1	820	73	35	2	948	51	0	11
568	56	17	9	696	76	43	0	824	73	8	2	952	50	6	11
572	57	12	8	700	76	59	0	828	72	39	2	956	49	13	11
576	58	7	8	704	77	13	0	832	72	9	2	960	48	20	12
580	59	1	8	708	77	26	0	836	71	38	3	964	47	26	12
584	59	54	7	712	77	38	0	840	71	6	3	968	46	31	12
588	60	46	7	716	77	48	0	844	70	32	3	972	45	36	13
592	61	38	6	720	77	57	0	848	69	57	3	976	44	41	13
596	62	28	6	724	78	4	0	852	69	21	3	980	43	46	13
600	63	17	6	728	78	9	0	856	68	45	4	984	42	50	14
604	64	5	5	732	78	13	0	860	68	7	4	988	41	55	14
608	64	53	5	736	78	15	0	864	67	29	4	992	41	0	14
612	65	39	5	740	78	16	0	868	66	49	4	996	40	4	15
616	66	24	5	744	78	15	0	872	66	9	5	1000	39	8	15
620	67	7	4	748	78	12	0	876	65	28	5	1004	38	12	16
624	67	49	4	752	78	9	0	880	64	46	5	1008	37	16	16
628	68	30	4	756	78	4	0	884	64	3	5	1012	36	21	16
632	69	10	4	760	77	58	0	888	63	19	6	1016	35	26	17
636	69	49	3	764	77	50	0	892	62	34	6	1020	34	30	17
640	70	26	3	768	77	40	0	896	61	48	6	1024	33	35	17



TAB. IV. Secundæ Æquationes Conjunctionum Satellitum cum Jove, five  
Generalis Æquatio Luminis. Addendæ.

Num. B.	0		100		200		300		400		500		600		700		800		900	
Æqu.	Æquat.		Æquat.		Æquat.		Æquat.		Æquat.		Æquat.		Æquat.		Æquat.		Æquat.		Æquat.	
	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
0	14	0	12	52	9	45	5	30	1	37	0	0	1	37	5	30	9	45	12	52
4	14	0	12	46	9	36	5	20	1	30	0	0	1	44	5	40	9	54	12	58
8	13	59	12	40	9	26	5	9	1	23	0	1	1	52	5	51	10	3	13	2
12	13	59	12	35	9	17	4	59	1	16	0	2	1	59	6	1	10	12	13	7
16	13	58	12	29	9	7	4	48	1	9	0	3	2	7	6	11	10	21	13	11
20	13	57	12	23	8	58	4	38	1	3	0	4	2	15	6	22	10	31	13	16
24	13	56	12	17	8	48	4	28	0	57	0	5	2	24	6	33	10	40	13	20
28	13	54	12	11	8	38	4	18	0	52	0	7	2	32	6	44	10	49	13	25
32	13	53	12	4	8	28	4	8	0	46	0	10	2	41	6	55	10	57	13	29
36	13	51	11	56	8	17	3	58	0	40	0	13	2	50	7	5	11	5	13	33
40	13	49	11	49	8	7	3	48	0	35	0	16	2	59	7	16	11	13	13	36
44	13	47	11	42	7	57	3	38	0	31	0	19	3	9	7	26	11	20	13	38
48	13	44	11	34	7	47	3	29	0	27	0	23	3	19	7	36	11	27	13	41
52	13	41	11	27	7	36	3	19	0	23	0	27	3	29	7	47	11	34	13	44
56	13	38	11	20	7	26	3	9	0	19	0	31	3	38	7	57	11	42	13	47
60	13	36	11	13	7	16	2	59	0	16	0	35	3	48	8	7	11	49	13	49
64	13	33	11	5	7	5	2	50	0	13	0	40	3	58	8	17	11	56	13	51
68	13	29	10	57	6	55	2	41	0	10	0	46	4	8	8	28	12	4	13	58
72	13	25	10	49	6	44	2	32	0	7	0	52	4	18	8	38	12	11	13	54
76	13	20	10	40	6	33	2	24	0	5	0	57	4	28	8	48	12	17	13	56
80	13	16	10	31	6	22	2	15	0	4	1	3	4	38	8	58	12	23	13	57
84	13	21	10	21	6	11	2	7	0	3	1	9	4	48	9	7	12	29	13	58
88	13	7	10	12	6	1	1	59	0	2	1	16	4	59	9	17	12	35	13	59
92	13	2	10	3	5	51	1	52	0	1	1	23	5	9	9	26	12	40	13	59
96	12	58	9	54	5	40	1	44	0	0	1	30	5	20	9	36	12	46	14	0
100	12	52	9	45	5	30	1	37	0	0	1	37	5	30	9	45	12	52	14	0

Tertiæ Æquationes Addendæ			T A B. V. Semidurationes Eclipsium Primi Satellitis Jovis.									
Num. A.	Æqua- tiones.	Num. A.	Num. A.	Semidu- rationes.	Nu. A.	Semidu- rationes.	Nu. A.	Semidu- rationes.	Nu. A.	Semidu- rationes.	Nu. A.	Semidu- rationes.
	I II			b. I II		b. I II		b. I II		b. I II		b. I II
0	3 30	1000	0	1 5 9	250	1 7 0	500	1 5 9	750	1 7 46		
20	3 29	980	10	1 4 56	260	1 7 15	510	1 4 53	760	1 7 57		
40	3 28	960	20	1 4 44	270	1 7 31	520	1 4 39	770	1 8 7		
60	3 25	940	30	1 4 33	280	1 7 45	530	1 4 26	780	1 8 15		
80	3 19	920	40	1 4 23	290	1 7 57	540	1 4 15	790	1 8 22		
100	3 12	900	50	1 4 13	300	1 8 7	550	1 4 7	800	1 8 26		
120	3 4	880	60	1 4 7	310	1 8 15	560	1 4 3	810	1 8 28		
140	2 56	860	70	1 4 4	320	1 8 22	570	1 4 1	820	1 8 30		
160	2 46	840	80	1 4 2	330	1 8 27	580	1 4 0	830	1 8 28		
180	2 34	820	90	1 4 0	340	1 8 28	590	1 4 3	840	1 8 26		
200	2 22	800	100	1 4 2	350	1 8 29	600	1 4 7	850	1 8 22		
220	2 10	780	110	1 4 3	360	1 8 27	610	1 4 13	860	1 8 16		
240	1 57	760	120	1 4 6	370	1 8 24	620	1 4 23	870	1 8 8		
260	1 44	740	130	1 4 12	380	1 8 17	630	1 4 35	880	1 8 0		
280	1 30	720	140	1 4 21	390	1 8 9	640	1 4 49	890	1 7 50		
300	1 17	700	150	1 4 31	400	1 7 58	650	1 5 4	900	1 7 37		
320	1 5	680	160	1 4 42	410	1 7 46	660	1 5 19	910	1 7 22		
340	0 53	660	170	1 4 55	420	1 7 31	670	1 5 36	920	1 7 8		
360	0 41	640	180	1 5 9	430	1 7 14	680	1 5 54	930	1 6 55		
380	0 31	620	190	1 5 23	440	1 6 58	690	1 6 10	940	1 6 40		
400	0 22	600	200	1 5 39	450	1 6 40	700	1 6 28	950	1 6 23		
420	0 14	580	210	1 5 55	460	1 6 20	710	1 6 46	960	1 6 8		
440	0 8	560	220	1 6 11	470	1 6 2	720	1 7 2	970	1 5 54		
460	0 4	540	230	1 6 26	480	1 5 45	730	1 7 17	980	1 5 37		
480	0 2	520	240	1 6 43	490	1 5 26	740	1 7 33	990	1 5 22		
500	0 0	500	250	1 7 0	500	1 5 9	750	1 7 46	1000	1 5 9		



*The Use of the foregoing TABLES; or Precepts for computing, by them, the Times when the Immerfions and Emerfions of Jupiter's Firft Satellite, happen under the Meridian of London.*

1. **I**N the *first Table*, intituled, *Epochæ Conjunctionum Mediarum*, &c. look for the Year propofed, and write out the Epocha of the mean Conjunction, or the Day, Hour, Minute, and Second thereof, together with it's corresponding Numbers, A, and B.

2. In the *second Table*, intituled, *Revolutions Primi Satellitis Jovis in Menfibus*, feek the Month in Question, and write out the Day, Hour, Minute, and Second, next lefs than the Time, on which the Eclipse fought, has already, or will hereafter happen; together with the Numbers A and B, annexed thereto.

3. Add the Numbers A together; and likewise the feveral Times collected from the Tables (*by the first and fecond Precept*) and the Sum of thefe will be the mean Time of the middle of the Eclipse required.

4. Enter the *third Table*, intituled, *Primæ Œquationes Conjunctionum*, &c. with the Sum of the Numbers A, (*obtained by the third Precept*) rejecting the Thoufands, and take out the firft Equation of the Conjunctions answering thereto; and alfo the Equation of the Number B.

5. Add together all the feveral Numbers B, thus equated, (rejecting the Thoufands) and write out the fecond Equation of the Conjunctions, answering to their Sum, from the *fourth Table*, intituled, *Secundæ Œquationes Conjunctionum*, &c. *five Generalis Œquatio Luminis*.

6. Enter the *fifth, or laft Table*, intituled, *Tertiæ Œquationes & Semidurationes Eclipsum*, &c. with the former Sum of the Numbers A, (*obtained by the third Precept*) and write out the third Equation corresponding thereto; and likewise the Semi-Duration of the Eclipse, which is to be fet down a-part.

7. To the mean Time of the middle of the Eclipse (*obtained by the third Precept*) add all the three Equations (*found by the fourth, fifth, and fixth Precepts*) and that Sum will difcover the exact Time of the middle of the Eclipse.

8. If the Sum of the Numbers B, (*Precept the fifth*) is lefs than five Hundred, fubtract the Semi-Duration of the Eclipse, from the Time before found (*by the feventh Direction*) and the

H

Remainder

Remainder is the exact Time of the Immersion required: But if the Sum of the Numbers B, is greater than five Hundred, add the same to the former Time, and it will give the exact Time of the Emerfion fought.

9. The Time obtained in this manner, is equal Time, which may be reduced to the apparent, or true, by the Tables of Equation of Time; that are every where to be met with.

*Note*, that in the Biffextile Year, after *February*, one Day must be subtracted from the Day of the Month.

We shall illustrate these Precepts by an Example or two, which will render them very plain and easy.

### E X A M P L E I.

*At Pekin in China, an Immersion of the First Satellite of Jupiter, was observed the 6th of January, 11<sup>h</sup> 22' 30" p.m. (O S) by Ign. Kogler. (Phil. Transf. No. 420. p. 182.) The Time when the same Eclipse happened under the Meridian of London, is required; and also the Difference of the Meridians of those Places.*

	Y	D	H	I	!!	No. A.	No. B.
<i>Epocha of the Conjunctions, (per Tab. 1.)</i>	1730. —	0	20	11	39	799	468
<i>Revolutions of the 1st Satellite, (per Tab. 2.)</i>	January.	5	7	25	48	1	14
							1 BEq.
<i>Mean Time of the Middle of the Eclipse</i>	—	6	3	37	27	800	
<i>1st Equation (per Tab. 3.)</i>	—		1	15	36		483
<i>2d Equation (per Tab. 4.)</i>	—			0	3		
<i>3d Equation (per Tab. 5.)</i>	—			2	22		
<i>Exact Time of the Middle of the Eclipse, (Eq. Time)</i>		6	4	55	28		
<i>Semi-Duration Subtract</i>	—		1	8	26		
						<i>Semi-duration.</i>	
						<i>b' "</i>	
<i>Exact Time of the Immersion, (Eq. Time)</i>	—	6	3	47	02	1	8 26
<i>Equation of Time, Subtract</i>	—			10	45		
<i>True Time of the Immersion at London</i>	—	6	3	36	17		
<i>True Time of the Immersion at Pekin (supra)</i>	—	6	11	22	30		

*Horary Difference of Meridians* — 7 46 13 *which, converted into Degrees of the Equator, gives 116 Deg. 13 Min. the Distance of the Meridian of Pekin from that of London: Wherefore, since the Time at London was less than at Pekin, the Longitude of Pekin, (according to this Observation) is 116 Deg. 13 Min. East from London.*

E X A M-



## E X A M P L E II.

*At Pekin in China, an Emerſion of the Firſt Satellite of Jupiter, was obſerved the 3d of May 9<sup>h</sup> 28' 45" p.m. (O S) by Ign. Kogler, (Phil. Tranſ. No. 420. p. 182.) The Time when the ſame Eclipse happened under the Meridian of London, is required; and alſo the Difference of the Meridians of thoſe Places.*

	Y	D	H	'	"	No. A.	No. B.
<i>Epocha of the Conjunctions (per Tab. 1.)</i>	1730	0	20	11	39	799	468
<i>Revolutions of the 1ſt Satellite (per Tab. 2.)</i>	May	2	2	53	21	28	309
							2 BEq.
<i>Mean Time of the Middle of the Eclipse</i>		2	23	05	00	827	
<i>1ſt Equation (per Tab. 3.)</i>				1	12		779
<i>2d Equation (per Tab. 4.)</i>					8		
<i>3d Equation (per Tab. 5.)</i>					2		
<i>Exact (Equal) Time of the Middle of the Eclipse</i>		3	00	29	20		
<i>Semi-duration add</i>				1	8		
							<i>Semi-duration.</i>
							<i>b</i>
<i>Exact (Equal) Time of the Emerſion</i>		3	1	37	49	1	8 29
<i>Equation of Time add</i>				4	4		
<i>True Time of the Immerſion at London</i>		3	1	41	53		
<i>True Time of the Immerſion at Pekin (ſupra)</i>		3	9	28	45		

*Horary Difference of Meridians* — 7 46 52 *which, converted into Degrees of the Equator, gives 116 Deg. 23 Min. the Difference of the Meridians of Pekin and London: Wherefore, ſince the Time at London was leſs than at Pekin, the Longitude of Pekin, (according to this Obſervation) is 116 Deg. 23 Min. Eaſt from London.*

F I N I S.

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Tentamina Medico-Physica, ad quasdam quæstiones, quæ Oeconomiam Animalem spectant, accommodata. Quibus accessit Medicinæ Statica Britannica. Authore Jacobo Keill, *M D.*

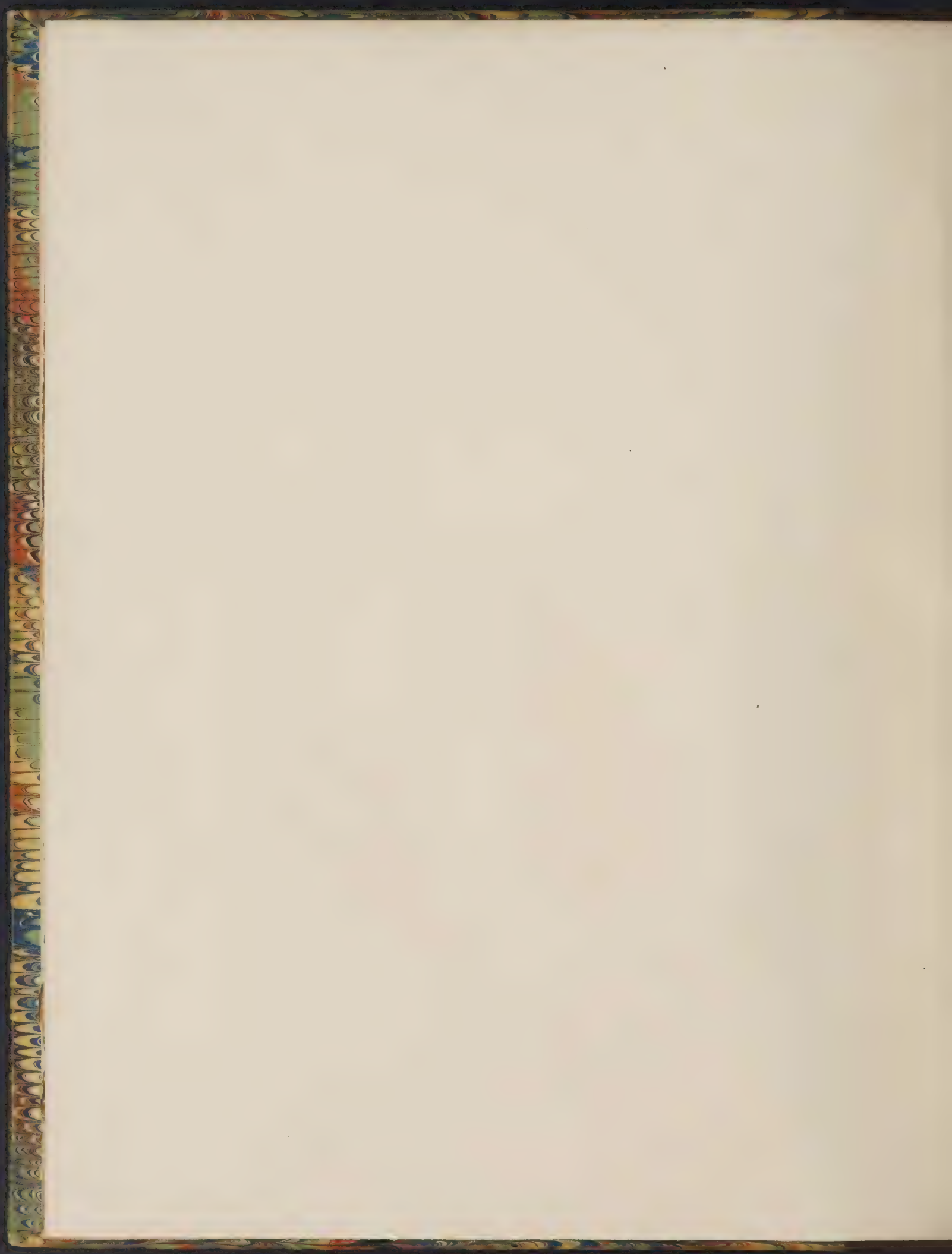




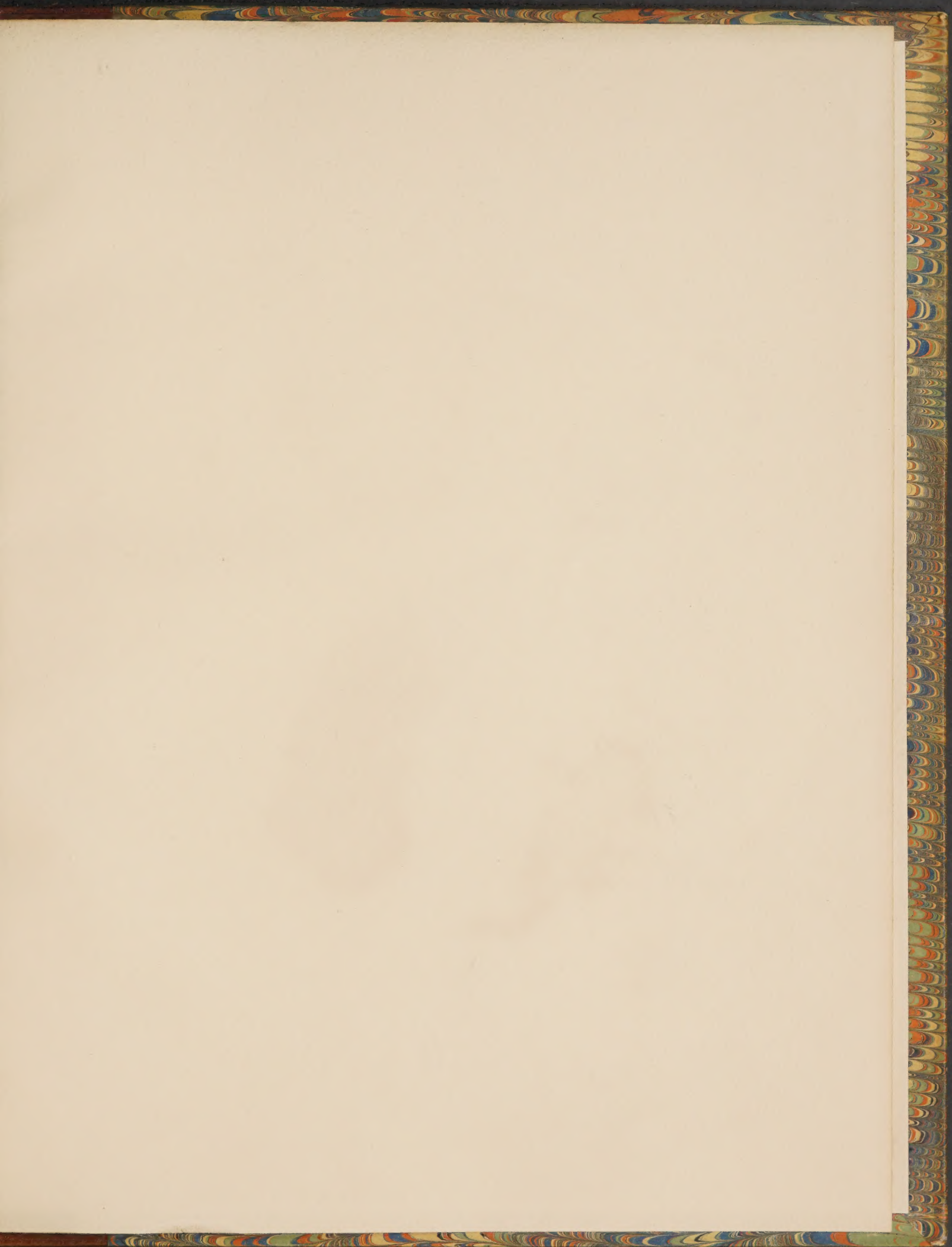


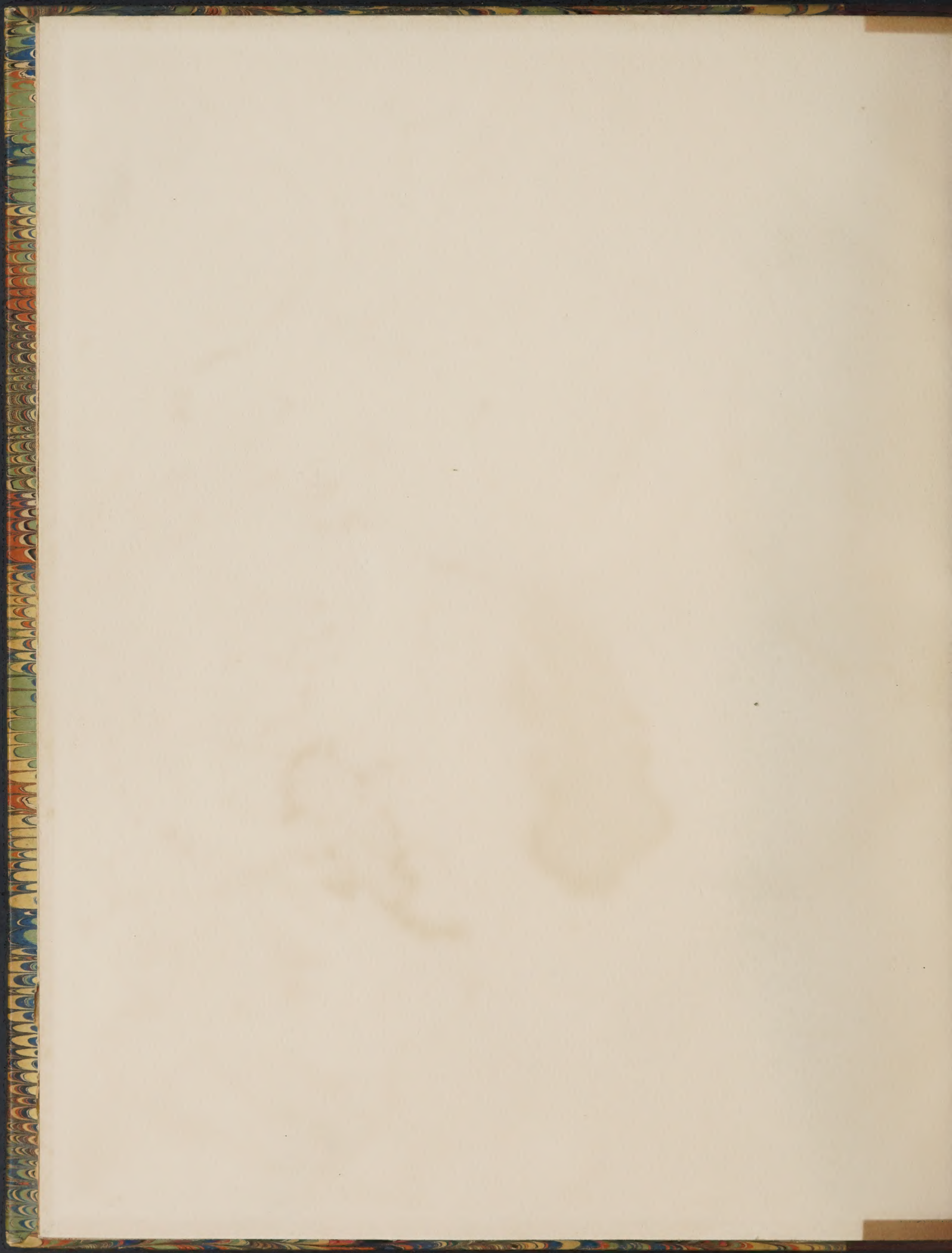














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